Check List the journal of biodiversity data

NOTES ON GEOGRAPHIC DISTRIBUTION

Check List 16 (2): 237–242
https://doi.org/10.15560/16.2.237

PENSOFT

Contribution to the mayflies (Insecta, Ephemeroptera) of Jordan

Ikhlas Alhejoj[1], Michel Sartori[2,3], Jean-Luc Gattolliat[2,3]

1 Department of Geology, University of Jordan, 11942 Amman, Jordan. **2** Musée Cantonal de Zoologie, Palais de Rumine, 1015 Lausanne, Switzerland. **3** Department of Ecology and Evolution, Biophore, University of Lausanne, 1015 Lausanne, Switzerland.
Corresponding author: Jean-Luc Gattolliat, jean-luc.gattolliat@vd.ch

Abstract

We here treat four unreported or poorly known mayfly species from Jordan: *Cheleocloeon soldani* Gattolliat & Sartori, 2008, *Cloeon vanharteni* Gattolliat & Sartori, 2008, *Baetis pacis* Yanai & Gattolliat, 2018, and *Caenis macrura* Stephens, 1835. They are reported and morphologically distinguished from other local relatives. *Caenis macrura* is widely distributed in the Palaearctic, *Ch. soldani* and *C. vanharteni* originated from the Arabian Peninsula, and *B. pacis* is restricted to a small area in southern Levant. We provide a complete checklist of the Jordanian mayfly fauna and deliver an identification key to the nymphal stages.

Keywords
Check list, identification key, Levant, new records.

Academic editor: Inês Corrêa Gonçalves | Received 28 October 2019 | Accepted 11 February 2020 | Published 6 March 2020

Citation: Alhejoj I, Sartori M, Gattolliat J-L (2020) Contribution to the mayflies (Insecta, Ephemeroptera) of Jordan. Check List 16 (2): 237–242. https://doi.org/10.15560/16.2.237

Introduction

The Kingdom of Jordan is a Middle-Eastern country in the southern Levant. With annual rainfall of less than 400 mm, natural aquatic habitats are scarce in most of the semi-arid country. The western part of Jordan, however, includes the eastern bank of a major section of Jordan River and numerous permanent and ephemeral streams in the Dead Sea network (Gattolliat et al. 2012; Alhejoj et al. 2014a). This area presents less hostile conditions for aquatic animals, and all of the findings reported below derive from there (Fig. 1).

Following recent field studies in Jordan, we collected data on mayflies (Ephemeroptera), including four species that were not previously reported. The data that we present here add to the new species and national records already reported by other recent publications (Gattolliat et al. 2012; Alhejoj et al. 2014a, 2014b; Ramadan and Katbeh-Bader 2018). However, previous information from Jordan is extremely scarce, hence the importance of the present study.

We include four mayfly species here and give information on their known distribution in Jordan, short biogeographical discussion, and diagnostic morphological characters of their nymphs with comparisons to other local species. We also present a complete list of the known mayfly species in the Kingdom of Jordan and an identification key to their nymphs.

Methods

During this last decade, field trips were carried out on the important streams and springs in the vicinity of the Jordan River and the Dead Sea to collect aquatic insects (i.e. western Jordan; Fig. 1). The field trips were mainly led by C. Monnerat (Centre Suisse de Cartographie de

Copyright *Alhejoj et al.* This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

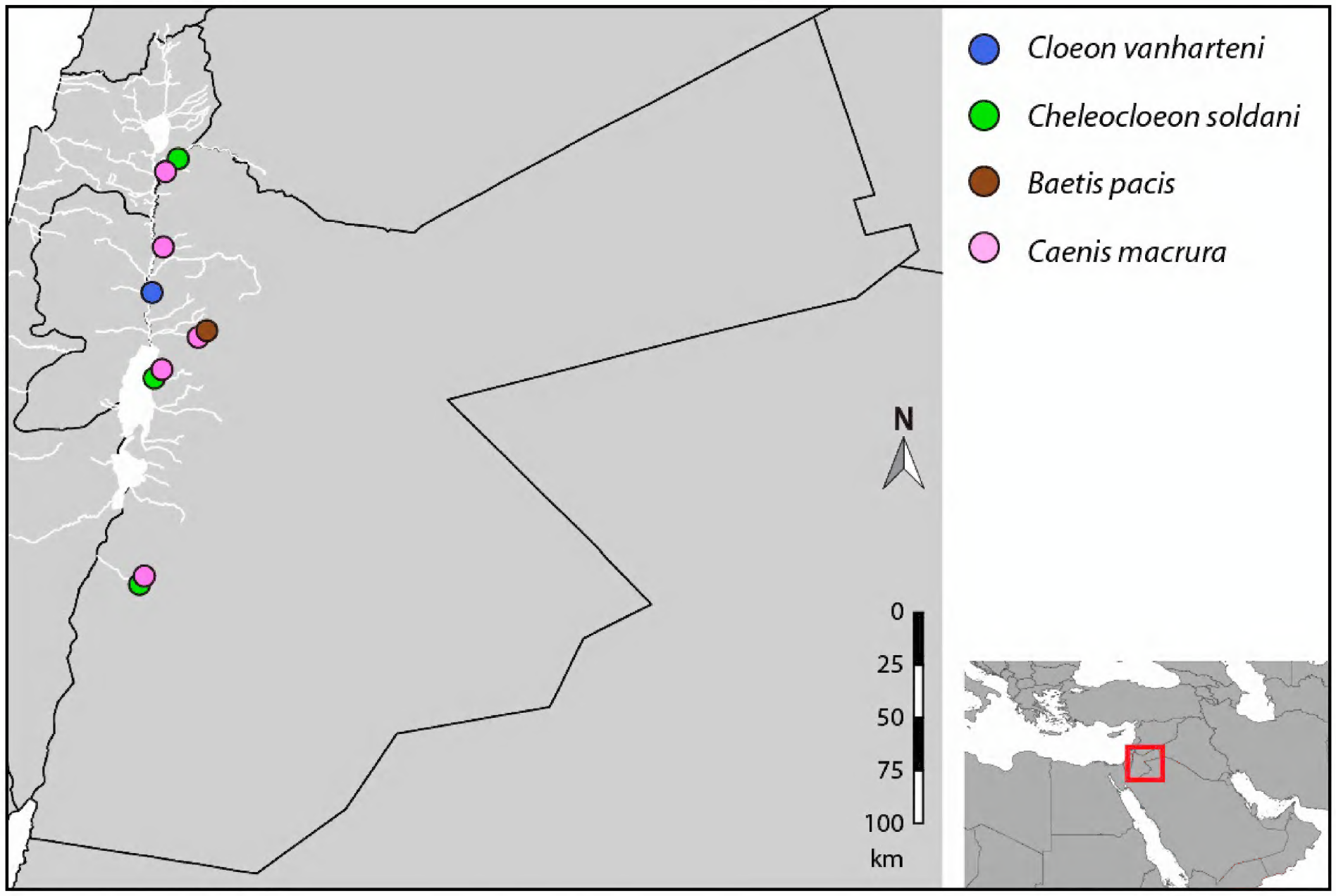

Figure 1. Occurrence of the newly reported species in Jordan. Map indicates main watercourses only in western Jordan, the study area.

la Faune, Neuchâtel, Switzerland), I. Alhejoj (University of Jordan, Amman, Jordan), and Z. Yanai (Museum of Zoology, Lausanne, Switzerland). Specimens were collected using a sampling net, and transferred to the lab in ethanol. Habitats were characterized, and water parameters, such as conductivity, pH, and temperature, were taken in the field using standard measuring devices (e.g. Eutech PCSTestr 35).

As no identification keys for the regional fauna are currently available, material was identified based on the original descriptions (for Baetidae: Gattolliat and Sartori 2008; Gattolliat et al. 2012; Yanai et al. 2018; and for Caenidae: Malzacher 1984, 1992). Subsequently, the specimens were morphologically compared to similar species in the rich collection of Middle-Eastern mayflies housed in Lausanne. Specimens of all species are preserved in ethanol and stored in the Museum of Zoology, Lausanne (MZL), Switzerland, except specimens of *Baetis pacis* Yanai & Gattolliat, 2018 from Jordan, which were never housed in MZL and are presumably lost.

The mitochondrial cytochrome *c* oxidase subunit I barcoding segment (COI) was sequenced for a specimen of *Ch. soldani*. We used the primers HCO2198 and LCO1490 (Folmer et al. 1994) and followed the extraction, amplification and sequencing protocols outlined by Yanai et al. (2018). The sequence was BLASTed in order to find the closest match available in GenBank. Molecular analyses were conducted in MEGA7 (Kumar et al. 2015). We used Kimura 2-parameter (K2P) to calculate genetic distances between individual sequences.

Results

Baetidae

Cheleocloeon soldani Gattolliat & Sartori, 2008
Figure 2A

Material examined. JORDAN • 1N; Wadi Ghuweir; 30.618°N, 035.5169°E; 341 m alt.; 30 May 2012; C. Monnerat leg. • 1N; small tributary to Yarmouk river; 32.678°N, 035.686°E; 6 Dec. 2018; D. Drukker leg. • 20N; Wadi Atun; 31.8158°N, 035.7918°E; 11 Mar. 2019; I. Alhejoj & Z. Yanai leg.; GenBank: MN944098.

Historical records. The species is known so far from the UAE (Gattolliat and Sartori 2008), Saudi Arabia (Salles et al. 2014), Israel, and the Palestinian Authority (Yanai et al. 2020).

Records in Jordan. In Jordan, this species is known from three distant localities (Fig. 1), near the Dead Sea and in the less arid north of the country.

Identification. As the only representative of the genus in the region, it is easily recognizable among the local Baetidae in having the combination of the following characters: single-lamellae gills, hindwings present in male and absent in female, rows of needle-like spines on distal margins of terga, long claws with two rows of minute teeth, and labial palp with a long, triangular distomedial projection, paracercus as long as cerci and absence of lateral spines on abdomen (Gattolliat and Sartori 2008; Kluge 2016). The COI sequence of *Ch. soldani*

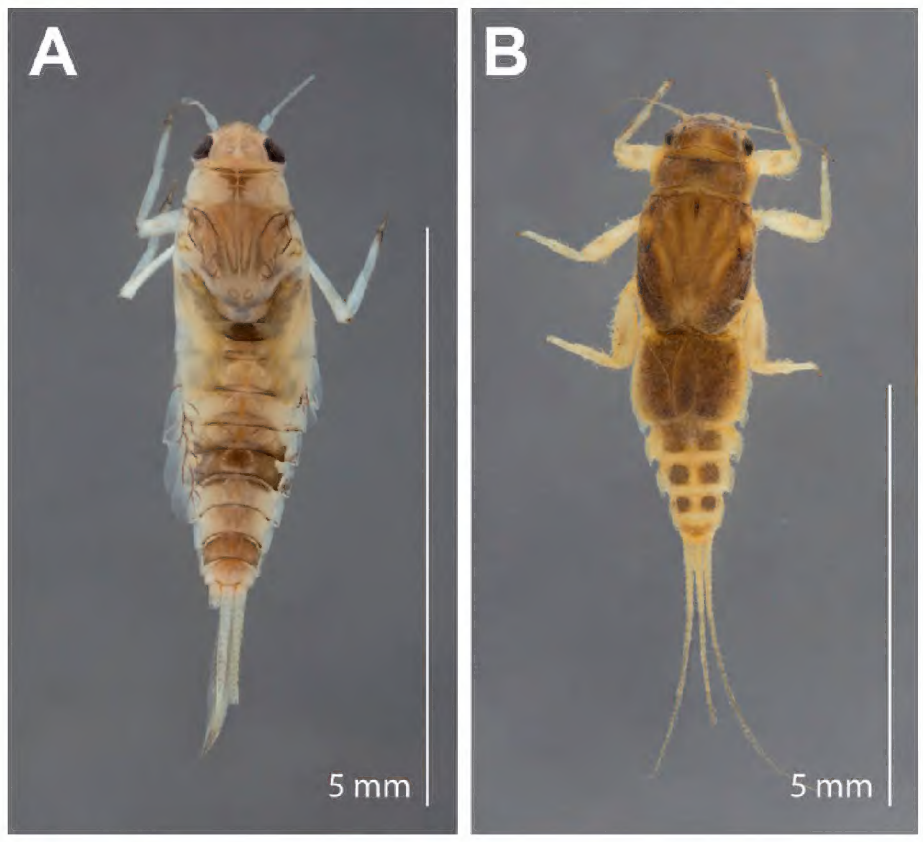

Figure 2. New mayflies recorded from Jordan, nymphs, *habitus*. **A.** *Cheleocloeon soldani*. **B.** *Caenis macrura*.

(GenBank accession number MN944098) confirms the similarity to a specimen sequenced from Saudi Arabia (Salles et al. 2014, HG935111, K2P distance 1.98%), and to another specimen from Israel (Yanai et al. 2020, MN958839, 0.61%).

Cloeon vanharteni Gattolliat & Sartori, 2008

Material examined. JORDAN • 3N; Karameh Dam; 32.025°N, 035.559°E; 16 Apr. 2013; I. Alhejoj leg.

Historical records. Described from UAE (Gattolliat and Sartori 2008), and subsequently only reported from Israel and the Palestinian Authority as well (Yanai et al. 2020).

Records in Jordan. The species is known from a single locality in Jordan. Based on the high environmental tolerance exhibited by this species (Gattolliat and Sartori 2008; Yanai et al. 2020), it is very likely that it is more abundant in Jordan. The distribution in Jordan is very provisional, as most of the prospected localities are in running water and the species is known to mainly occur in standing water (Gattolliat and Sartori 2008).

Identification. Compared to other local *Cloeon* species, its nymph can be identified by having a relatively small body with large gill lamellae and extremely long claws. The female adult is the only *Cloeon* from this area without any distinguishable wing pattern.

Baetis pacis Yanai & Gattolliat, 2018

=*Baetis* sp.: Alhejoj et al. 2014b.

=*Baetis pacis*: Yanai et al. 2018: 70–74, figs 4E, 14, 15.

Material. Soneh Spring, Wadi Hisban Mar.–Apr. 2012. Material was not fully examined as it was never housed in MZL and is presumably lost.

Distribution. The species is known from northern Israel and from a single locality in the Palestinian Authority (Yanai et al. 2018). It is now formally reported from Jordan (see below). In Jordan *B. pacis* is only known from a single locality, Wadi Hisban (Alhejoj et al. 2014b). Only a few individuals were encountered in the field in 2012, and repeated visits in the following years to the site failed to collect this species again.

Identification. With clearly distinguished morphological characters (Yanai et al. 2018), this species cannot be confused with any other *Baetis* species in southern Levant. Alhejoj et al. (2014b) reported it as *Baetis* sp. Yanai et al. (2018) suggested that this report from Jordan corresponds to *B. pacis*. Observation of the distinct general habitus, especially of the extremely reduced paracercus, confirmed their hypothesis.

Caenidae

Caenis macrura Stephens, 1835

Figure 2B

Material examined. JORDAN • 7N; Wadi Ghuweir; 30.618°N, 035.5169°E; 341 m alt.; 30 May 2012; C. Monnerat leg. • 10N; Wadi Hisban; 31.8158°N, 035.7918°E; 11 Mar. 2019; I. Alhejoj & Z. Yanai leg. • 13N; Wadi Hisban, big spring; 31.8366°N, 035.7982°E; 11 Mar. 2019; I. Alhejoj & Z. Yanai leg. • 200N; Wadi Arab; 32.6148°N, 035.6246°E; 12 Mar. 2019; I. Alhejoj & Z. Yanai leg. • 1N; Wadi Rajib; 32.2465°N, 035.6135°E; 12 Mar. 2019; I. Alhejoj & Z. Yanai leg.

Distribution. *Caenis macrura* is a widespread West Palearctic species found throughout the Middle East (e.g. Koch 1988), including Israel and the Palestinian Authority (Samocha 1972; Malzacher 1992). Like in Israel, it was the most abundant *Caenis* species in our sampling in 2019. However, distinguishing it from the co-occurring *C. antoniae* Malzacher, 1992 is extremely complicated. Perhaps this explains why Gattolliat et al. (2012) failed to identify *C. macrura* among the *C. antoniae* in the material they examined. Some of the "*Caenis* sp." mentioned by Alhejoj et al. (2014b) most certainly belonged to this species too.

Identification. The species differs from the other local congeners by having prominent lateral abdominal spines, a relatively deep indentation in sternite IX, as well as wing pads covered with rows of large microtrichia, often attaching or overlapping (Malzacher 1992). This difficult last character is the only one allowing for a certain distinction from *C. antoniae*. The species identification is therefore rather difficult; furthermore, most species of *Caenis* present considerable intraspecific variations (Malzacher 1984).

Discussion

The four mayfly species treated here have geographic ranges that vary considerably. *Caenis macrura*, found across most of west and central Palaearctic (Malzacher 1984, 1992), displays the most widespread distribution

pattern of the species discussed. Southern Levant is already known to be its southernmost limit (Malzacher 1992), and its occurrence in Jordan is therefore expected. It is probably very common in Jordan, but due to its morphological resemblance to *C. antoniae*, it may have been unreported. *Cheleocloeon soldani* is well adapted to conditions in desert wadis, as suggested by the previous reports in UAE and Saudi Arabia (Gattolliat and Sartori 2008; Salles et al. 2014) and by the new occurrences reported here from Wadi Atun and Wadi Ghuweir in Jordan; however, this species' record from the humid environment of the Yarmouk River suggests that it may have wider ecological niche, or it may behave opportunistically. Similarly, *Cloeon vanharteni* was also originally described from UAE and occurs in desert conditions too. It most probably occurs in additional wadis in arid parts of Jordan. *Baetis pacis* has the most restricted distribution range among the treated species and is known only from a handful of populations in southern Levant.

The name *Cloeon dipterum* (Linnaeus, 1761) was earlier mentioned by Gattolliat et al. (2012), Alhejoj et al. (2014a, 2014b), and Ramadan and Katbeh-Bader (2018) for the most common mayfly species in Jordan, but new molecular and morphological evidence suggest that *C. dipterum* of these authors is in fact an undescribed species, whose identity should be clarified soon (J.-L. Gattolliat, S. Rutschmann, unpublished data). Until then, we strongly recommend avoiding using "*Cloeon dipterum*" in publications and prefer "*Cloeon* cf. *dipterum*" instead. Furthermore, *C. vanharteni* is also known from Jordan, and *C. perkinsi* Barnard, 1932 is reported from Israel (Yanai et al. in press) and may occur in Jordan as well. With other species that might occur in Jordan, identifications must be made with extreme caution.

The newly reported species join the seven known species from Jordan (Malzacher 1992; Gattolliat et al. 2012; Alhejoj et al. 2014b). A complete checklist of Jordanian mayflies is provided in Table 1, and an identification key to the nymphal stages, which are the most useful for ecologists and practitioners, is given below. Available information on mayflies in Jordan in past and current studies is limited to eastern tributaries of the Lower Jordan River and the Dead Sea (Fig. 1). Most of the country is arid and additional wetlands and streams are rare, except for the more humid parts in northern Jordan. If these habitats are investigated further, we assume that more locality records of these species will be found.

Thanks to international collaboration, we are able to compare material and knowledge, and present this important contribution to entomologists and freshwater ecologists in the region.

Identification key to the nymphs of mayflies (Ephemeroptera) in Jordan

1 Body stocky, flattened. First pair of gills reduced, second pair forming large gill covers, covering remaining gills ..... **Caenidae**, *Caenis*, 3
– Body slender. All gills visible and more-or-less similar in shape, no gill cover 2

2 Gills composed of single- or double-lamellae, which may be plate-like or soft, never with finger-like processes ..... **Baetidae**, 5
– Gill 1 lanceolate, gills 2–7 composed of double plate-like lamellae, each with three slender, subequal finger-like processes, similar to *Ch. arabica*, Sartori & Gillies, 1990 (Sartori and Gillies 1990: figs 12, 14) .. ... **Leptophlebiidae**, *Choroterpes* (*Euthraulus*) *ortali*

3 Abdominal segments with short posterolateral spines, segments VIII–IX with only 5–7 short lateral setae. Posterior indentation in sternum IX shallow, sometimes semicircular (Malzacher 1992: fig. 6) .... *Caenis parabrevipes*
– Abdominal segments with long posterolateral spines with broad bases, segments VIII–IX with numerous long lateral setae. Posterior indentation in sternum IX deep (Malzacher 1992: fig. 5)..... 4

4 Microtrichia on wing pads small, with wide gaps between them (Malzacher 1992: fig. 5e). Indentation in sternum IX notch shaped (Malzacher 1992: fig. 5a–c). In male nymphs the base of antennal pedicel

Table 1. Checklist of the mayflies of Jordan. Distributions of the species are based on Malzacher (1992), Sartori (1992), Gattolliat and Sartori (2008), Bauernfeind and Soldán (2012), Gattolliat et al. (2012), and Yanai et al. (2018).

Taxa	First report from Jordan	Species distribution
BAETIDAE		
Baetis monnerati Gattolliat & Sartori, 2012	Gattolliat et al. 2012	South Levant
Baetis pacis Yanai & Gattolliat, 2018	Current study	South Levant
Nigrobaetis vuatazi Gattolliat & Sartori, 2012	Gattolliat et al. 2012	South Levant
Cloeon cf. *dipterum* Linnaeus, 1761	Gattolliat et al. 2012	Holarctic
Cloeon vanharteni Gattolliat & Sartori, 2008	Current study	Arabian Peninsula and South Levant
Procloeon pennulatum Eaton, 1870	Gattolliat et al. 2012	Holarctic
Cheleocloeon soldani Gattolliat & Sartori, 2008	Current study	Arabian Peninsula and South Levant
CAENIDAE		
Caenis antoniae Malzacher, 1992	Malzacher 1992	South Levant
Caenis parabrevipes Malzacher, 1992	Gattolliat et al. 2012	South Levant
Caenis macrura Stephens, 1835	Current study	Palearctic
LEPTOPHLEBIIDAE		
Choroterpes (*Euthraulus*) *ortali* Sartori, 1992	Gattolliat et al. 2012	South Levant

dilated (Malzacher 1992: fig. 3c) ..... *Caenis antoniae*
– Microtrichia on wing pads large, with narrow gaps between them (Malzacher 1992: fig. 2a). Indentation in sternum 9 deep and basally rounded. In male nymphs the base of antennal pedicel not dilated .... *Caenis macrura*

5 Gill double-lamellae rounded; upper lamella slightly smaller than lower (Gattolliat and Sartori 2008: fig. 31). Hind wing pads absent.....*Cloeon*, 6
– Gill single-lamellae plate-like, or double with very reduced upper lamella. Hind wing pads present (except for females of *Ch. soldani*)..... 7

6 Labial palp broad. Claws moderately elongated (Gattolliat et al. 2008: fig. 9). Cerci with well marked median dark band ..... *Cloeon* cf. *dipterum*
– Labial palp slender. Claws significantly elongated (Gattolliat and Sartori 2008, Fig. 35). Cerci with only a faded dark band ..... *Cloeon vanharteni*

7 Claws long (nearly half tarsus), with numerous small or vestigial denticles. Paracercus length subequal to cerci 8
– Claws short (0.25–0.3× tarsus), with fewer than 13 noticeable denticles. Paracercus no longer than 0.6× cerci 9

8 Labial palp with prominent thumb-like disto-medial projection (Gattolliat and Sartori 2008: Fig. 18). Gills single-lamellae. Lateral abdominal spines absent ... . *Cheleocloeon soldani*
– Labial palp with small thumb-like disto-medial projection. Gills double-lamellae, upper lamella reduced. Lateral abdominal spines present at least on segments VIII–X ..... *Procloeon pennulatum*

9 Carina between compound eyes present (Gattolliat et al. 2012: fig. 19). Third segment of labial palp quadrangular ..... *Nigrobaetis vuatazi*
– Carina between compound eyes absent. Third segment of labial palp conical ..... *Baetis*, 10

10 Paracercus at least 0.5 the length of cerci. Claws without pair of subapical setae (Gattolliat et al. 2012: fig. 34) ..... *Baetis monnerati*
– Paracercus extremely reduced, no longer than 10 segments (Alhejoj et al. 2014b: fig. 2B; Yanai et al. 2018: fig. 4E). Claws with pair of subapical setae (Yanai et al. 2018: fig. 15B) ..... *Baetis pacis*

Acknowledgements

We thank Christian Monnerat for the gift of precious material, Zohar Yanai for his help in the field, Daan Drukker for the record of *Cheleocloeon soldani* from the Yarmouk River, and Marion Podolak for the assistance with the molecular lab work. We want to sincerely thank Inês Corrêa Gonçalves, Paulo Cruz, Roman Godunko, and Pavel Sroka for their valuable comments on the manuscript. Christian Monnerat thanks the Royal Society for the Conservation of Nature (RSCN), especially Enas Sakkijha (head of research section) and her successor Ehab Eid, for their interest in our survey of mayflies in Jordan between 2009 and 2012 and is also grateful to Ahmad Katbeh-Bader (University of Jordan, IMA) and Zuhair Amr (Jordan University of Science and Technology, Irbid) for their welcome and support.

Authors' Contributions

IA collected material in the study area; JLG and MS identified it. IA, MS and JLG wrote the manuscript.

References

Alhejoj I, Bandel K, Salameh E (2014a) Macrofaunal and floral species in Jordan and their use as environmental bio-indicators. The University of Jordan, Amman, 259 pp.

Alhejoj I, Salameh E, Bandel K (2014b) Mayflies (order Ephemeroptera): an effective indicator of water bodies conditions in Jordan. International Journal of Scientific Research in Environmental Sciences 2: 346–354. http://doi.org/10.12983/ijsres-2014-p0361-0370

Barnard KH (1932) South African may-flies (Ephemeroptera). Transactions of the Royal Society of South Africa 20: 201–259.

Bauernfeind E, Soldán T (2012) The mayflies of Europe (Ephemeroptera). Apollo, Ollerup, 781 pp. https://doi.org/10.1163/9789004260887

Folmer O, Black M, Hoeh W, Lutz R, Vrijenhoek R (1994) DNA primers for amplification of mitochondrial cytochrome *c* oxidase subunit I from diverse metazoan invertebrates. Molecular Marine Biology and Biotechnology 3: 294–299.

Gattolliat J-L, Sartori M (2008) Order Ephemeroptera. Arthropod Fauna of the UAE 1: 47–83.

Gattolliat J-L, Hughes SJ, Monaghan MT, Sartori M (2008) Revision of Madeiran mayflies (Insecta, Ephemeroptera). Zootaxa 1957: 52–68.

Gattolliat J-L, Vuataz L, Sartori M (2012) First contribution to the mayflies of Jordan. Zoology in the Middle East 56: 91–110. https://doi.org/10.1080/09397140.2012.10648945

Kluge NJ (2016) Redescription of the genus *Cheleocloeon* Wuillot & Gillies 1993 (Ephemeroptera: Baetidae) with descriptions of three new species from Zambia and Uganda. Zootaxa 4067: 135–167. https://doi.org/10.11646/zootaxa.4067.2.2

Koch S (1988) Mayflies of the northern Levant (Insecta: Ephemeroptera). Zoology in the Middle East 2: 89–112. https://doi.org/10.1080/09397140.1988.10637565

Kumar S, Stecher G, Tamura K (2015) MEGA7: Molecular Evolutionary Genetics Analysis version 7.0 for bigger datasets. Molecular Biology and Evolution 33: 1870–1874. https://doi.org/10.1093/molbev/msw054

Linnaeus C (1761) Fauna Svecica sistens Animalia Sveciae regni: mammalia, aves, amphibia, pisces, insect, vermes. Distributa per classes & ordines, genera & species, cum differentiis specierum, synonymis auctorum, nominibus incolarum, locis natalium, descriptionibus insectorum. Editio altera, auctior. Stockholmiae: Sumtu & Literis Direct. Laurentii Salvii. https://doi.org/10.5962/bhl.title.46380

Malzacher P (1984) Die europäischen Arten der Gattung *Caenis* Stephens (Insecta: Ephemeroptera). Stuttgarter Beiträge zur Naturkunde Serie A (Biologie) 373: 1–48.

Malzacher P (1992) Mayflies from Israel (Insecta, Ephemeroptera) II. —Caenidae. Mitteilungen der Schweizerischen Entomologischen Gesellschaft – Bulletin de la Société Entomologique Suisse 65: 385–394.

Ramadan DM, Katbeh-Bader A (2018) Diversity of aquatic and semi-aquatic insects in Wadi Al-Walah in Jordan. Zoology and Ecology 28: 117–138. http://doi.org/10.1080/21658005.2018.1464145

Salles FF, Gattolliat J-L, Angeli KB, De-Souza MR, Gonçalves IC,

Nessimian JL, Sartori M (2014) Discovery of an alien species of mayfly in South America (Ephemeroptera). ZooKeys 399: 1–16. https://doi.org/10.3897/zookeys.399.6680

Samocha M (1972) Ephemeroptera of Israel. MSc thesis, Tel Aviv University, Tel Aviv, 111 pp.

Sartori M (1992) Mayflies from Israel (Insecta; Ephemeroptera). I. Heptageniidae, Ephemerellidae, Leptophlebiidae, Palingeniidae. Revue Suisse de Zoologie 99: 835–858

Sartori M, Gillies MT (1990) Further records of mayflies (Insecta: Ephemeroptera) from the Arabian Peninsula. Leptophlebiidae and Baetidae. Fauna of Saudi Arabia 11: 10–17.

Yanai Z, Gattolliat J-L, Dorchin N (2018) Taxonomy of *Baetis* Leach in Israel (Ephemeroptera, Baetidae). ZooKeys 794: 45–84. https://doi.org/10.3897/zookeys.794.28214

Yanai Z, Gattolliat J-L, Sartori M (2020) Contribution to the mayflies (Insecta: Ephemeroptera) of Israel and the Palestinian Authority. Check List 16 (2): 229–236. https://doi.org/10.15560/16.2.229

Yanai Z, Graf W, Terefe Y, Sartori M, Gattolliat J-L (in press) Redescription and range extension of the Afrotropical mayfly *Cloeon perkinsi* (Ephemeroptera, Baetidae). European Journal of Taxonomy.